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Development of a Computer Software System for Mining Operations Based on Three Dimensional Theory

Unsolicited Proposal No. L7-026

FINAL REPORT

for submission to the Scientific Authority

by

LYNX Geosystems Inc

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MICROMEDIA

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EXECUTIVE SUMMARY

The overall objective of the project was to develop a complete 3D computer system for surface and underground mining which would extend the capabilities and advantages of new 3D modelling technology into the environment of mining operations. The project was based on the existing LYNX Mining System and, in particular, on the new 3D Component Modelling technology developed by the LYNX R + D team.

The specific (itemized) objectives of the project were to extend and enhance the existing 3D capabilities of the LYNX Mining System to encompass all of the requirements of a general mining system. This would be achieved by incorporating the new 3D Component Modelling technology with existing LYNX System facilities concerned with mine planning and scheduling, mine surveying, mine production control, and rock mechanics engineering. This comprised the creation of system application modules to suit the technical computing requirements of each of these mining disciplines.

The project can be classified as highly successful. The results are included in Release 2 of the system which is fully operational and has already been installed at mine sites and offices in Canada and the rest of the western hemisphere. The system is highly regarded by those already using it and is gaining recognition by the mining industry as the technology leader in its field. The total work load of the project was accomplished within the original budget and within a fifteen month time frame; ie. a three month extension to the forecasted project time frame was required. The work content and emphasis of the project differed in some areas from the initial schedule of items. These changes were in line with the stated project policy of maintaining an awareness of, and responding to, evolving industry requirements and priorities.

The resulting system contains all of the generic capabilities, functions and facilities required to satisfy the requirements of operating mines, and most of the application processes and facilities, which are based on the former. Where changes or omissions to the format or implementation of the original work items have occurred these have been noted, with causes and justification, in the Technical Discussion below.

Throughout the course of the contract the LYNX development team paid strict attention to established standards, guidelines and preferences of the mining industry. These correspond closely to the recommendations of the report "Computer Program Specifications for the Ontario Mining Industry", CANMET Project No. 6-9009, March 1987. They include the supermicro graphics workstation as the preferred hardware platform, the UNIX operating system, Fortran 77 and C programming languages, and the computing industry standard Graphics Kernel System (GKS). The development team has also maintained its commitment to providing transportable systems. Release 2 of the system is already operational on Hewlett-Packard and SUN workstations and will shortly be available on the new IBM line of graphics workstations.

Other factors which influenced the final outcome of the project included the following.

- In line with its policy of responsiveness to mining industry requirements, priorities and preferences the development team has maintained an attitude of "not re-inventing the wheel". In technical computing areas already well served by existing, established (third party) software packages the development emphasis has been on providing efficient interfaces to these packages rather than duplication of the facilities. Particular areas affected by this policy include survey reduction, report generation, CAD and stress analysis.
- In line with its policy of providing the end user of the system with maximum flexibility, the development team has wherever possible provided open-ended, generic facilities rather than hard-coded, customized facilities tied to specific requirements or applications. This ensures that the system can be applied to the widest possible range of mining situations.

RÉSUMÉ DE LA DIRECTION

Le projet visait principalement à développer un progiciel tridimensionnel global pour les opérations de surface et souterraines, afin d'introduire dans l'environnement minier les capacités et avantages de la technologie modélisatrice 3-D. Le projet s'apuyait sur le système minier LYNX préexistant et, en particulier, sur la nouvelle technologie modélisatrice 3-D par composantes élaborée par l'équipe R&D de Lynx.

Les buts spécifiques (par élément) du projet consistaient en l'extension et l'amélioration du potentiel 3-D du système minier LYNX préexistant, afin d'y inclure toutes les exigences d'un système minier global. La proposition prévoyait incorporer la nouvelle technologie de modélisation 3-D par composantes dans les domaines suivants du système LYNX préexistant: planification-cédulation minière, arpentage minier, contrôle de la production minière et ingénierie de la mécanique des roches. De ceci découla la création de modules d'application qui satisfont les demandes informatiques techniques de ces disciplines minières.

Le projet peut être étiquetté comme succès. Les résultats inclus dans la version 2 du système en démontrent la valeur, telle que vérifiée dans les bureaux d'ingénierie minière au Canada et dans d'autres pays à économie de marché. Le système a la faveur des usagers actuels et s'impose rapidement comme chef de file dans son domaine d'application. Le projet initialement proposé fut entièrement réalisé dans les limites budgétaires et ce, en quinze mois, c'est-à-dire trois mois de plus que ce qui avait été prévu au départ. Le contenu du projet diffère par endroits de la conception initiale. Ces changements répondent au critère énoncé au début de se maintenir à la fine pointe des exigences et priorités industrielles et d'y répondre au besoin.

Le système qui en résulte contient toutes les capacités génériques, fonctions et aménagements requis afin de satisfaire les besoins de mines en opération, ainsi que la majorité des options et possibilités d'utilisation des progiciels antérieurs. Lorsque des changements ou omissions dans le format ou l'implantation des éléments de base sont devenus nécessaires, ils ont été signalés, et leurs causes et justifications incluses dans la discussion technique qui suit.

Tout au long du déroulement du contrat, l'équipe de réalisation du projet chez Lynx s'est assurée de respecter normes, lignes directrices et préférences établies par l'industrie minière. Celles-ci se rapprochent des recommandations du rapport "Spécifications de logiciels informatiques pour l'industrie minière ontarienne", projet CANMET No 6-9009, mars 1987. Elles commprennent la station supermicro à écran graphique comme plate-forme de travail, le système de gestion UNIX, les langages de programmation FORTRAN 77 et C, ainsi que la norme graphique industrielle GKS (Graphics Kernel System). L'équipe de réalisation s'est également assurée de la transférabilité du produit à divers environnements matériels. La version 2 du progiciel opère déjà sur stations Hewlett-Packard et SUN, et sera très bientôt adaptée à la nouvelle ligne IBM de stations graphiques.

D'autres facteurs ont influencé la forme finale du rapport, entre autres:

- Conformément à sa politique de répondre aux attentes, priorités et préférences de l'industrie minière, l'équipe de réalisation a respecté le principe de 'ne pas réinventer la roue'. Dans les domaines techniques où du logiciel informatique de tierces parties satisfaisait la demande, l'attention fut concentrée sur la construction d'interfaces efficaces plutôt qu'à reproduire ces logiciels. Les domaines particuliers affectés par cette politique incluent les données d'arpentage, la sortie de rapports, la CAO et l'analyse de contraintes.

- Conformément à sa politique de procurer un maximum de flexibilité aux usagers du système, l'équipe de réalisation a décidé d'offrir des modules génériques polyvalents, plutôt que des logiciels standards rigides liés à des besoins ou applications particuliers. Ceci assure le client du système qu'il peut l'utiliser dans une gamme de situations minières extrêmement variée.

INTRODUCTION

The results of the project are all contained within the version of the LYNX Mining System referred to as release 2. The facilities provided by the system, including those developed within the project, are described in detail by the system User Documentation.

The Technical Discussion below is limited to presenting, for each of the original contract work items, the achievements, changes and omissions which occurred. Where major changes or omissions occurred these were generally driven by one or more of the following factors.

- A response to evolving mining industry requirements, priorities and preferences.
- An improvement to overall system efficiency.
- Interfacing to existing (third party) facilities for which the mining industry had shown a preference.

In all cases of omission the work effort saved was re-applied to items of higher priority (within the original framework of the contract), to the overall benefit of both the system and the mining industry.

A major achievement within the framework of the contract was the development and implementation of new surface handling, modelling and mapping technology. This technology had significant impact on the efficiency of application of the system in the areas of mine planning, survey and production control.

Other achievements which were outside of the framework and scope of the contract but occurred within the same time-frame are also included in Release 2 of the system. These include the following.

- A major re-organization and rationalization of the system structure in the interests of overall system efficiency in operation and application. This had some impact on the outcome of the project in that several of the application modules and their contents were shuffled in the process.
- A similar rationalization of the system menu and user documentation.
- A port of the system to the new generation of RISC based SUN workstations. This development is of immediate benefit to CANMET since it ensures compatibility of the system with their new SUN workstation installation.
- Considerable ongoing development and enhancement of all modules of the system, including those not affected by the project, performed under LYNX's software maintenance and support commitments to existing clients.
- Under the terms of the contract CANMET receives the full benefit of all of these achievements free of charge.

TECHNICAL DISCUSSION

The following is a detailed statement of work for each of the project work items comprising the eight system modules which it was anticipated would result from this project. Allowances for alpha-site testing and preparation of final documentation were included for each module.

In each case, the statement of work is followed by a report for the item detailing the results, achievements, omissions, changes, etc. which occurred.

The project work items were classified according to the level of software development required in each case. The three work item classes of software development were defined as follows:

- CLASS 1: enhancement, extension or modification of an existing system module which already incorporates the new 3D solids technology.
- CLASS 2: substantial enhancement and extension of an existing system module by the addition of new 3D solids technology.

- CLASS 3: development of a new system module by integration and re-structuring of existing system facilities drawn from several sources and incorporation of new 3D solids technology.

CONTRACT ITEM 1: UNDERGROUND MINE DESIGN

This project work item was a CLASS 1 software development. The objective was to extend and enhance the existing LYNX System module for underground mine excavation and development design to provide the additional design facilities listed below.

a) Provision of facilities for handling cross-sections other than rectangular in all design routines concerned with auto-generation of mine development model components.

User survey results determined that this was a low priority development item; development effort was therefore limited to providing the generic system enhancements required to facilitate further development in this area at a later stage. This was accomplished via enhancement to the unit and component naming facilities and to the component wild-card sorting and retrieval facilities.

b) Provision of facilities for specification of grade (slope) in all design routines concerned with auto-generation of mine development model components.

User survey results determined that this was a high priority development item; considerable development effort was therefore expended in this area. The result is a highly interactive, efficient facility for semi-automatic generation of modelling components representing mine development of any configuration from any orientation. This facility is embodied within the C-LINE routine, which has become the prime vehicle for rapid definition of models representing mine development.

c) Provision of facilities for auto-assembly of standard model units (sets of components) as opposed to single components; for mine excavation design and mine development design models.

The generic facilities for auto-assembly of units (sets) of components were provided by streamlining of the existing ASSEMBLE routine and enhancements to the unit and component naming conventions and wild-card sorting and retrieval facilities. It is anticipated that much future development will be performed in this area as users become more familiar with the concepts involved.

d) Enhancement of existing mining reserves reporting routines to provide more flexibility in terms of multiple cutoff grade specification and reporting, and reporting of multiple deposit grades.

The existing mining reserves reporting facilities were considerably enhanced to provide more flexible formatting facilities and the reporting of multiple grades. In addition a facility was provided for export of mining reserves information to standard ASCII format files which can be readily accessed by industry standard computing facilities such as Lotus 123 and dBase. This provides the user with familiar facilities for re-formatting reports to suit local mining conditions and standards. This is in line with the development philosophy of providing an open-ended system which can interface with accepted (third-party) software packages. Facilities for specification and reporting of reserves for multiple cut-off grades were provided within the Mine Planning and Scheduling module.

CONTRACT ITEM 2: UNDERGROUND MINE PLANNING AND SCHEDULING

This project work item was a CLASS 2 software development. The objective was to enhance and extend the existing LYNX System module for Mine Activity and Resource Scheduling (modified for underground conditions) by incorporating the new 3D solids modelling technology.

The development items covered below were all incorporated in a generic mine planning and scheduling module which satisfies the requirements of both underground and surface mining, ie. the two system modules anticipated under contract items 2 and 6 were replaced by the provision of one generic module. Because the industry requirements for mine planning and scheduling are very loosely defined and vary widely in scope at this stage it is anticipated that much future development will be performed on this module as users become more familiar with the highly interactive facilities already provided.

a) Provision of facilities for interactive graphics selection of model units and components.

The generic facilities required for this item were provided by enhancements to the unit and component naming conventions and the wild-card sorting and retrieval facilities.

b) Provision of facilities for interactive specification of model component excavation rate, activity start and end dates, mining resource allocation and mining constraints; storage of this information by component in the model database (provision exists); system output is a mine planning model.

All of the above facilities are now provided in the generic Mine Planning and Scheduling module.

c) Enhancement of existing model display facilities to allow time-based (color coded) displays of the mine planning model.

This item was accomplished by providing facilities for effecting component code changes which control the colour in which components are displayed.

d) Provision of a facility for generation of a mine planning inventory file consisting of mine planning model units and associated tonnages, volumes and grades by material type (code).

This item was completely provided for. In addition facilities for export of the mine planning inventory file to an external (third-party) scheduling system of the user's choice were also provided.

e) Interfacing of the existing Mine Activity and Resource Scheduling module (suitably modified for underground conditions) with the mine planning model and the mine planning inventory file.

This item was completely provided for.

f) Enhancement of existing time-based reporting facilities (graphical and tabular) for mine planning and scheduling.

Considerable development effort was expended in this area to provide flexible, interactive reporting facilities. Further development in this area is anticipated as users become familiar with application of the existing facilities.

CONTRACT ITEM 3: UNDERGROUND MINE SURVEY

This project work item was a CLASS 3 software development. The objective was to develop a new LYNX System module which incorporated the new 3D solids modelling technology with parts of the existing Surface Mine Survey module, modified for underground mining conditions.

As part of the re-organization and rationalization of the system structure and menus, all underground mine survey facilities were incorporated with production control facilities into one Underground Production Control module, ie. the two system modules anticipated under contract items 3 and 4 were replaced by the provision of one combined module.

a) Modification of existing facilities for input and reduction of survey field notes to suit underground conditions; storage and retrieval of same from a survey database.

Because firstly, mine survey standards and conventions vary widely from one geographical location to another and secondly, survey reduction requirements are generally well covered by either accepted, PC-based (third party) software packages or by total survey station facilities, this function was provided by a generic facility for import of reduced XYZ coordinate information. This information is imported in standard ASCII file format into the new, generic Map Data Management facilities.

b) Modification of existing facilities for input and reduction of total survey station recordings, via a suitable instrument interface, to suit underground conditions; storage and retrieval of same from a survey database.

Refer to item 3(a) above.

c) Provision of facilities similar to those existing for the surface mine survey database maintenance.

Survey database requirements are fully provided for by the new, generic map database facilities.

d) Provision of facilities similar to those existing for display and plotting of survey information.

Display and plotting of survey information are fully provided for within the new, generic Map Data Handling module.

e) Provision of an interface between the survey database and existing 3D solids modelling facilities; conversion of surveyed excavation profiles to (unit width) model components.

These facilities are fully provided for by the new surface handling technology and facilities.

f) Provision of facilities for automatic interpolation of excavation profile components to 3D model components.

Refer to item 3(e) above.

g) Provision of facilities for specification of model component dating, etc. (refer item 2(b) above) for 'as mined' conditions, and storage in the 3D solids model database (provision exists); system output is a mine production model.

Refer to item 4 below.

CONTRACT ITEM 4: UNDERGROUND MINE PRODUCTION CONTROL

This project work item was a CLASS 3 software development. The objective was to develop a new LYNX System module which incorporated the new 3D solids modelling technology with extended reporting facilities from the existing Mine Activity and Resource Scheduling module.

Production Control facilities were incorporated with Underground Survey facilities to form a combined module, refer to item 3 above.

a) Provision of facilities for time-based (color coded) 3D displays (refer item 2(c)) of the mine production model produced under item 3(g) above.

Refer to item 2(c) above.

b) Provision of enhanced time-based reporting facilities (graphical and tabular) for volume, tonnage and grade similar to item 2(f) above.

Refer to item 2(f) above.

c) Provision of new facilities for extended (flexible) mine production and development reporting; including comparison of planned vs. measured (surveyed) quantities, and planned vs. measured vs. mill-head tonnage and grade.

Refer to item 1(d) above. These capabilities are currently provided for by the reserves report export capabilities, ie. reserves can be manipulated externally to provide whatever comparisons are required.

CONTRACT ITEM 5: SURFACE MINE DESIGN

This project work item was a CLASS 2 software development. The objective was to extend and enhance the existing LYNX System module for surface (open-pit) mine excavation design by incorporating the new 3D solids modelling technology.

All of the existing surface mine design application facilities were successfully integrated with the 3D Component Modelling Technology, including pit optimization, conical pit expansion and pit plan definition, and combined with the additional new design facilities covered below. This was achieved primarily via the new Map Data Management facilities and the new Surface Handling technology developed under the contract.

a) Provision of facilities for interactive definition and display of 3D solid model components for excavation design by bench.

This item was completed in full.

b) Provision of facilities for interactive definition and display of 3D solid model components for excavation design on section.

This item was completed in full.

c) Modification of existing mining reserves reporting routines to suit the above.

This item was completed in full.

d) Modification of the existing facility for generation of a mine planning inventory file to suit the above (refer item 2(e).

Refer to item 2(e) above for a description of generic facilities.

CONTRACT ITEM 6: SURFACE MINE PLANNING AND SCHEDULING

This project work item was a CLASS 1 software development. The objective was to modify the LYNX 3D System module developed above for underground mine planning and scheduling (refer 2.2.2) to suite surface mining requirements.

The facilities anticipated under this item were provided by the generic Mine Planning and Scheduling module produced under item 2 above.

a) As per item 2(a), re-packaged.

b) As per item 2(b), re-packaged.

c) As per item 2(c), re-packaged.

CONTRACT ITEM 7: SURFACE MINE PRODUCTION CONTROL

This project work item was a CLASS 1 software development. The objective was to modify the LYNX 3D System module developed above for underground mine production control (refer item 4) to suit surface mining conditions.

All of the generic facilities required for Surface Mine Production Control have been provided, including those of Surface Mine Surveying, in one module, refer to item 3 above. This was achieved largely by the integration of new Map Data Management facilities and the new generic Surface Handling technology.

a) Modification of the module produced under item 4 above to accommodate minor reporting differences for surface mining conditions.

Refer to item 4(c) above.

CONTRACT ITEM 8: ROCK MECHANICS ENGINEERING

This project work item was a CLASS 3 software development. The objective was to develop a new LYNX System module which incorporated the new 3D solids modelling technology with existing system facilities for finite element stress/strain analysis, and geotechnical mapping and analysis. The new module would also make use of existing system facilities for 3D geostatistical modelling of rock mechanics parameters.

With the exception of item 8(f) generic facilities for all of the items noted below are now available within the system; in the interests of not having to support an unnecessary and substantial duplication of code these facilities will probably not be generated as a separate module unless future circumstances dictate otherwise. Item 8(f) was omitted in line with the development policy of providing interfaces to suitable external (third-party) software packages where these exist in a form which has been generally accepted by the industry. In this case the necessary interface was produced under item 8(e) below.

a) Provision of facilities for display of measured (mapped) geotechnical and rock mechanics information in suitable graphical format on plans and sections; re-packaging of existing system facilities.

These requirements were provided by the new Map Data Management facilities and enhanced system display facilities.

b) Provision of facilities for creation of 3D solids models of geotechnical/rock mechanics regions (domains) by interactive interpretation of the above displays; the modelling capability exists within the system at present.

These requirements were provided by enhancements to existing interpretation and modelling facilities.

c) Provision of facilities for creation of 3D block geostatistical models (by kriging and/or inverse distance approach) of geotechnical/rock mechanics parameters (eg. rock quality, material strength, etc.); this modelling capability exists within the system at present.

These requirements were provided by enhancements to existing geostatistical modelling facilities.

d) Provision of facilities for intersection and display of a 3D solids model of mine excavation and development with the above models; determination of mine excavation and development in bad ground, etc. (essentially a mining reserves reporting exercise); estimation of quantities of rock reinforcement, etc. (roof bolting, mesh guniting, etc.); generation of graphical and tabular reports.

These facilities were provided by enhancements to existing reserves reporting and volumetrics facilities.

e) Provision of facilities for generation and display of sections through intersections of the above models (3D solid RM domains, 3D block RM parameters, 3D solid mine model) utilizing existing 3D solid modelling technology; output of a section file which interfaces with existing finite element mesh generation facilities for creation of 2D finite element models.

These facilities were provided by existing sectional display facilities and by provision of a new ASCII file export capability.

f) Provision of facilities for linear and non-linear (time-dependent and/or elastoplastic) 2D finite element analysis of the above mining sections utilizing existing system capabilities; enhance graphical and tabular reporting of results (deformations, stress/strain contours, principle stress vectors).

These facilities were not provided; refer item 8 above.

APPENDIX 1

PRODUCT INFORMATION

LYNX SYSTEM: PRODUCT SUMMARY *(January 1990)*

SUMMARY

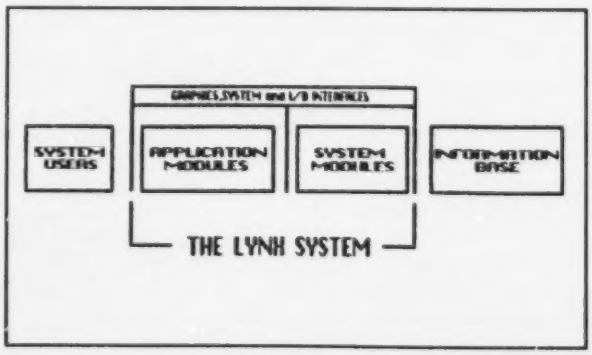
The LYNX System is designed to operate on a UNIX based, graphics workstation platform. It complies with industry standards for language (Fortran 77 & C), graphics (GKS), and is transportable across a wide range of single-user, multi-user, and networked hardware configurations. The system is highly modular in structure and thus configurable to user requirements. It consists of a technical core of SYSTEM MODULES, which is a mandatory requirement for any configuration, surrounded by a layer of APPLICATION MODULES, which are user-specific and address the applications functions required by different mining disciplines and environments.

The system is based on LYNX's 3D Component Modelling technology, ensuring an integrated solution and information flow between all phases of a mining operation.

SYSTEM MODULES

SYSTEM MANAGEMENT: LYNX user interface, graphics screen handler and menu structure. This mandatory module also includes peripheral drivers and system utilities (project back-up, restore and system configuration)

MODELLING FUNCTIONS: This mandatory module incorporates the LYNX system 3D Component Modelling core functions (3D solids modelling, surface handling, geostatistics) and additional system facilities such as volumetrics, 3D perspective displays and data file operations.



USERS	APPLICATION MODULES	SYSTEM MODULES	INFORMATION BASES
GEOLOGY	DATA MANAGEMENT	SYSTEM MANAGEMENT	PROJECT DETAILS
ENGINEERING	DATA ANALYSIS	MODELLING FUNCTIONS	DRILLHOLES
PLANNING	GEOLOGICAL INTERPRETATION		MAP INFORMATION
PRODUCTION	U/G MINE DESIGN		MODELS
MANAGEMENT	OPEN PIT MINE DESIGN		INVENTORIES
	PLANNING & SCHEDULING		SCHEDULES
	PRODUCTION CONTROL		PRODUCTION DATA
			EXCAVATIONS

APPLICATION MODULES

Information Management

DATA MANAGEMENT: Management of raw project data such as exploration drillholes, production data and map data. User defined project set-up and reformatting of existing projects. Drillhole data management, incorporating data entry, reporting and data import utilities. Map data management and display including graphical entry/edit and digitizing facilities and map utilities (transfer, import, copy). Map features include contours, traverses, discrete points (with attributes), line features and icons.

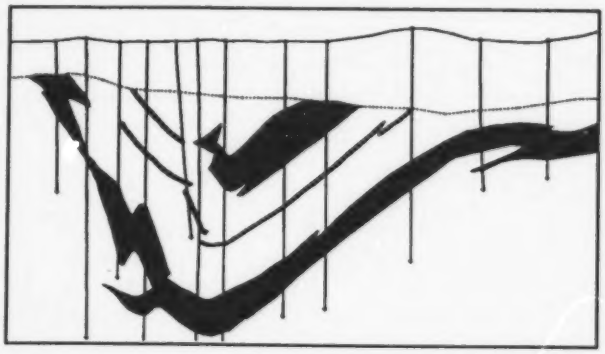
Geology

DATA ANALYSIS: Display and projection of exploration drilling and sample information: display formats include values, histograms, ranges, colour bars, contours and isopach projections. Mathematical analysis of geological information using classical statistics and variogram analysis, with options for data selection and sorting.

GEOLOGICAL INTERPRETATION: Application module for the construction and manipulation of 3D shapes of complex geological structures. Overlay of drillhole and map data, including map profiling. Surface handling and triangulation utilities for the modelling of bedded deposits. Regularization of drill sample data via drillhole compositing. Geostatistical modelling of numeric grade/quality data using inverse distance or kriging. Display and contouring of geostatistical models. Geological reserves analysis and reporting, including ASCII data file exporting.

CONTACT:
LYNX GEOSYSTEMS INC, 400-1199 West Pender St., Vancouver, B.C., V6E 2R1
Phone: (604) 682-5484 Fax: (604) 669-3659

LYNX SYSTEM: PRODUCT SUMMARY *(Continued)*



Engineering

UNDERGROUND MINE DESIGN: Application module for the design of underground development and ore excavation layouts using 3D component modelling. Automatic and interactive ramp and development generation, component assembly facilities, manipulation of mining surfaces, background display of geological and geostatistical models, rapid volumetric analysis. Reporting of excavation volumes, volumes of intersection and mining reserves. Plans, sections and 3D perspective views of geological & mining models.

OPEN PIT MINE DESIGN: Mine design application facilities ranging from initial designs using pit optimization though to final pit and ramp design, and mining reserves. 3D Lerchs-Grossmann optimization algorithm for preliminary open pit designs. Interactive methods of pit design including conical pit expansion, plan mine design, dump design and 3D solids modelling. Reporting of excavation volumes, volumes of intersection and mining reserves based on 3D component model of geology. Plans, sections and 3D perspective views of geological and mining models.

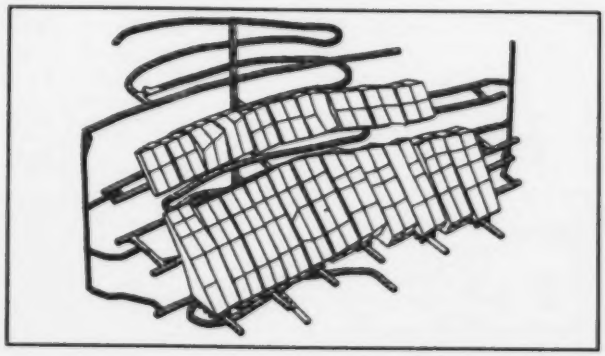
Planning

PLANNING & SCHEDULING: Simulation of mining production based on mine planning units defined in 3D component modelling. Planning periods may cover all, or a portion, of the life of a mine using Critical Path Networking. Operations include definition of mine planning units, generation of mine activities, definition of geometric constraints and working calendar, activity and equipment sequencing, interactive production planning. Output is generated in graphical (Gantt charts, bar charts) or tabular form.

Production

UNDERGROUND PRODUCTION CONTROL: Management of surveyed "as mined" excavation limits based on total station, digitizer, keyboard or ASCII file input of reduced 3D coordinates. Definition of 3D component models of actual mining limits honouring all surveyed data. Generation of production grade models based on in-situ sample values. Volumetrics and mining reserves of "as mined" development and production units. Analysis of production quantities and grades.

SURFACE MINE PRODUCTION CONTROL: Management of surveyed "as mined" surface excavation advances based on total station, digitizer, keyboard or ASCII file input of reduced 3D coordinates. Automatic definition of 3D component shapes filling excavation surface differences which honour all surveyed data. Generation of production grade models based on in-situ (eg. blast-hole) sample values. Volumetrics and mining reserves of "as mined" development and production units. Analysis of production quantities and grades. ■



PRODUCT INFORMATION

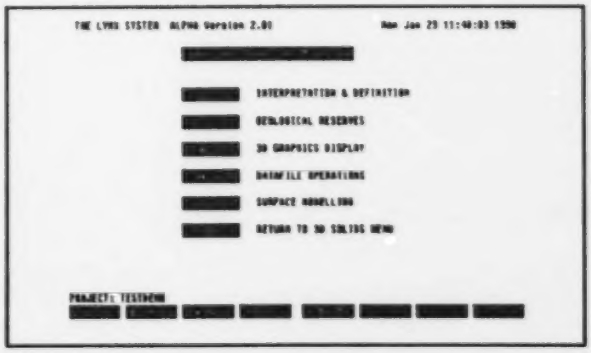
LYNX SYSTEM: SYSTEM MANAGEMENT MODULE *(January 1990)*

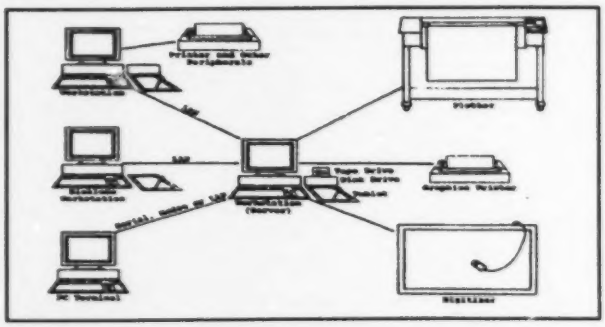
SUMMARY

The System Management module provides the framework upon which the modelling functions and applications modules are supported and integrated. The module contains the menu system and structure; the interactive graphics interface through which the user communicates with the system; file import, export and interfacing routines for communication with other (external) systems; device driver routines for all peripheral hardware devices; and system utility routines for frequently used facilities such as contouring, triangulation, digitizing, etc. This module is a mandatory part of any LYNX system configuration.

Menu System

The menu system is organized along the lines of a heirarchical, pyramid structure, with each menu option accessing several options within the level immediately below it. At the highest level the menu options are organized by user discipline (geology, engineering, etc.); at the next level by application (u/g mine design, open pit mine design, etc.); and at the third and lower levels by specific application functions. The menu system integrates the system modules and applications modules and provides high-level user access to all of the applications functions. Lower-level user access is provided via the interactive graphics interface.





Interactive Graphics Interface

The interactive graphics interface provides the primary means of user:system communication. It integrates the functionalities of a high-definition, colour graphics, display, a keyboard with special function keys, and an interactive device (graphics tablet or mouse) to provide a highly efficient communications medium. The format of the display screen is designed specifically for geological and mining applications and incorporates standard features for function key definitions/options; user prompts and responses; viewplane orientation reporting; cursor location tracking and reporting; local and global coordinate grid displays; and background displays of relevant information in graphical formats.

Peripheral Devices

The LYNX system supports a selection of peripheral devices such as hard-copy, multi-pen plotters, digitizing tablets, graphics and text printers, disk drives, and tape drives, all of which are mandatory items for standard workstation configurations. The system also supports multi-user workstations and networked (LAN) configurations. Device drivers for all of the above are contained within the system management module.

System Import, Export and Interfacing Facilities

Data import facilities are provided for drillhole and map

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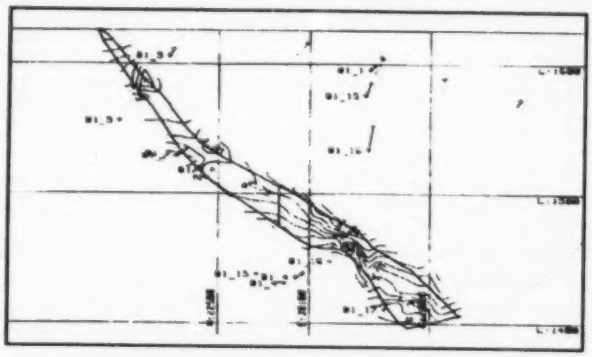
LYNX SYSTEM: SYSTEM MANAGEMENT MODULE *(Continued)*



file information in standard ASCII formats from externally generated files. Geological and mining reserves reports may be exported to ASCII format files for subsequent import to external software systems such as dBASE, LOTUS, etc. Similarly, plot files in standard HPGL format may be generated for subsequent plot spooling in batch mode. HPGL plot files may also be converted to DXF format for import to external CAD systems such as AutoCAD.

The LYNX system may be interfaced directly with the microLYNX, PC based system, for direct import of drillhole information. In this way, microLYNX may be utilized as an efficient, front-end, data capture and review facility for the workstation system.

System Utilities

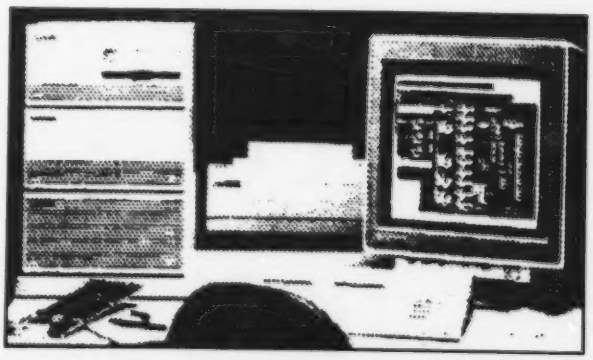
2D plans and sections may be produced on any plane. Overlays of maps in the form of projections or intersections are available throughout the system. Intersection with geological models and mine designs may be displayed. Interactive zoom, and section cutting make view re-definition simple and easy. 3D perspectives from any angle may be produced, incorporating geology, structure, topography and other surfaces, etc. 3D hidden line removal is used for finished plots.

Plotting – any graphics display may be plotted. User-defined scales, grids, and titles complete the specification.

Digitizing – interactive digitizing is one of the main graphical data input facilities. Digitizing may be performed from any 3D orientation of a planar surface.

Contouring – full contouring facilities, based on Delauney triangulation are used for contouring grades, topographic surfaces, etc. in a wide range of graphical formats.

System Utilities – a full range of menu driven utilities are included for data backup and restore, workstation configuration, project, model and design specification, reformatting of project databases, etc. ■



PRODUCT INFORMATION

LYNX SYSTEM: MODELLING FUNCTIONS MODULE *(January 1990)*

SUMMARY

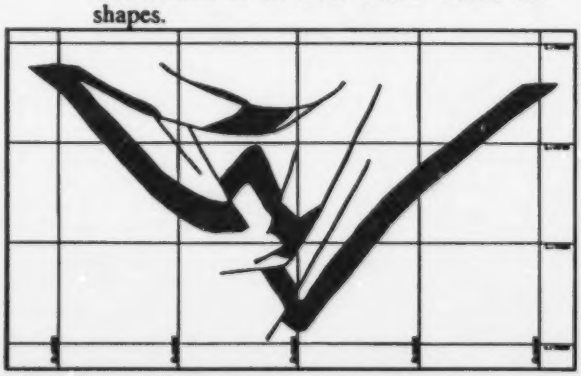
3D COMPONENT MODELLING by LYNX is a major technological advance for the mining industry and the environmental geosciences in technical computing. This achievement is the result of the integration of innovative numerical modelling, geostatistics and graphics technologies, and its practical application to computing in mining. The result is a realistic, precision modelling solution which eliminates the approximations and limitations of traditional block modelling, wireframes and gridded modelling.

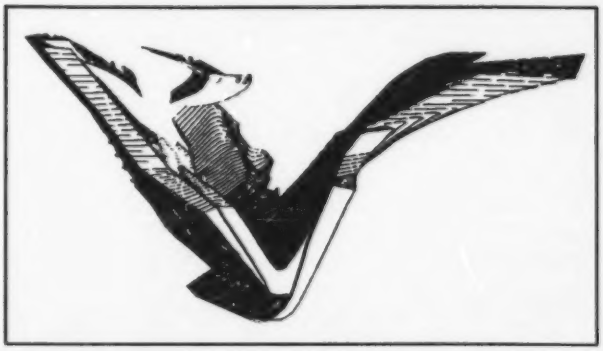
The Modelling Functions Module utilizes 3D COMPONENT MODELLING to provide the base for a technical computing solution which is applicable and accessible to all phases of mining operations as well as diverse geological environments. This ensures both the integration and integrity of technical computing applications as well as a smooth flow of information between the mining disciplines of geology, engineering, planning and production.

FUNCTIONAL DESCRIPTION

3D COMPONENT MODELLING comprises three key integrated modelling elements which form the nucleus of the LYNX System.

- Solids Modelling for the representation of complex, irregular 3D shapes and volumes.
- Geostatistics for predicting and modelling the distribution of attribute values within the shapes.





- Surface Handling for transforming surfaces, and the spaces between, into modelling components.

These modelling techniques are integrated by the addition of 3D Volumetrics facilities, a modelling Database, and an Interactive Graphics (CAD) Interface; all of which are tailored to the requirements of the mining disciplines (geology, engineering, planning and production).

The full power of 3D COMPONENT MODELLING is made available to the user through the Applications Modules for each phase of mining operations, described in detail elsewhere.

3D Solids Modelling

Solids Modelling is a proven technique for numerical modelling, analysis and graphical display of irregular 3D shapes and their contained volumes. The theory is based on solids of integration and has its origins in analytical geometry and integral calculus.

Complex, irregular shapes in space are modelled by assemblies of 3D solids components. Each of these represents a solid of integration. The individual components are of arbitrary user-defined form and orientation. The user is therefore free to model to any level of detail which is relevant to his analytical requirements. A significant concept in the development of the methodology is the manner in which shapes and components are defined. 3D COMPONENT MODELLING is designed for the specific requirements of geological interpretation and excavation design.

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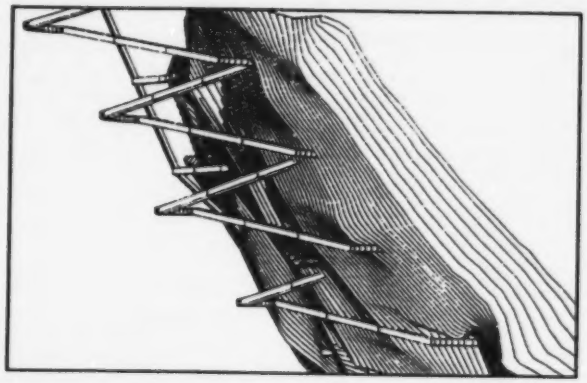
PRODUCT INFORMATION

LYNX SYSTEM: MODELLING FUNCTIONS MODULE *(Continued)*



The methodology provides for the determination of the exact geometry of any section, at any 3D orientation, through a shape for display purposes. This also has direct application to the precise calculation of the volume of any mining or geological shape, and beyond this to the precise calculation of the volumes of intersection between shapes.

3D COMPONENT MODELLING thus eliminates the approximations and limitations of the traditional block modelling and wireframe approaches to the representation of shapes, surfaces and volumes.

Geostatistical Modelling

The integration of geostatistical interpolation techniques within 3D COMPONENT MODELLING provides the means for representing the variation of numerical attributes such as grade and quality within irregular 3D shapes. The attribute values are interpolated (predicted) from isolated exploration sample values using kriging or other techniques and under the full parametric control of the user.

The modelling functions create 3D arrays of attribute values, each of which is associated with a region of influence which can be precisely intersected by geological and mining shapes. The volumetrics facilities are thereby extended to the determination of grade or quality within a shape, or within an intersection of shapes. The result is precise reporting of geological and mining reserves.

The surface and volume modelling constraints imposed on geostatistical modelling by the traditional methods are no longer a consideration. Geostatistical arrays can be oriented, sized and spaced specifically to suit geostatistical considerations, such as exploration data distribution, variation and orthotropy.

Surface Handling

The powerful Surface Handling facilities incorporated within 3D COMPONENT MODELLING provide the means for automatic and interactive triangulation of geological and mining surfaces, and the transformation of these, and the voids between surfaces, into triangular 3D solids components. The resulting geological and mining units are fully compatible with all of the modelling functions and processes described. The application of 3D COMPONENT MODELLING is thereby efficiently extended to large-scale, thin seam type deposits and surface mining methods.

The approximations of traditional rectangular gridded modelling are completely eliminated by triangulation and 3D COMPONENT MODELLING; all observations are honoured, detail is incorporated as required, and discontinuities are efficiently handled.

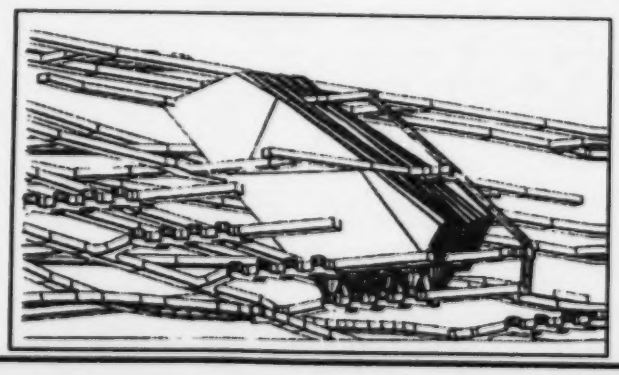
Volumetrics and Reserves

The ability to overlay and intersect 3D shapes representing excavation limits, geological units and geostatistical regions of influence, and to determine the resulting volumes of intersection and associated grade and quality values by numerical integration, is a key factor in the successful application of 3D COMPONENT MODELLING. This ability is provided by the 3D volumetrics facilities within the modelling functions. These in turn provide the basis for precise, selective reporting of volume, tonnage and grade/quality results for geological and mining reserves.

Geological & Mining Database

3D COMPONENT MODELLING utilizes a database concept which is designed to meet the requirements of all mining disciplines (geology, engineering, planning and production). The flexibility of the unit and component naming facilities allow the user to design and implement naming, sorting and selection conventions which match those of the project and mining phase. Powerful wild card selection facilities complement the database design.

Geological, geostatistical and mining models are stored and maintained separately, thereby ensuring their integrity. They can be overlayed, intersected or combined at any stage for display, analysis and reporting purposes, thus providing an integrated solution to all phases of a mining operation. ■



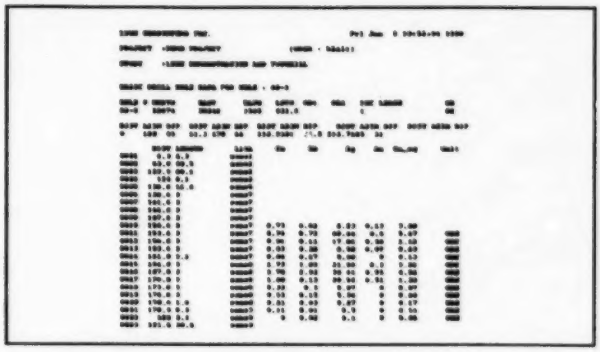
PRODUCT INFORMATION

LYNX SYSTEM: DATA MANAGEMENT MODULE *(January 1990)*

SUMMARY

The Data Management (Applications) Module offers a wide range of facilities for efficient management and ready access to all types of basic data relevant to mining operations, including project data, drillhole data, map data (reference and attribute information), and production data. The user is provided with numerous options and flexibility in terms of data formatting for storage, reporting and display of all types of data. These facilities, combined with efficient data access for reporting and editing purposes, present the user with the necessary tools to manage the large and varied amounts of data which typically form the knowledge base of any mining operation.

The Data Management Module stores all available data for a project in a structure and format that is readily accessible from all other modules in the system, thus ensuring data integrity and a smooth data flow throughout the system.

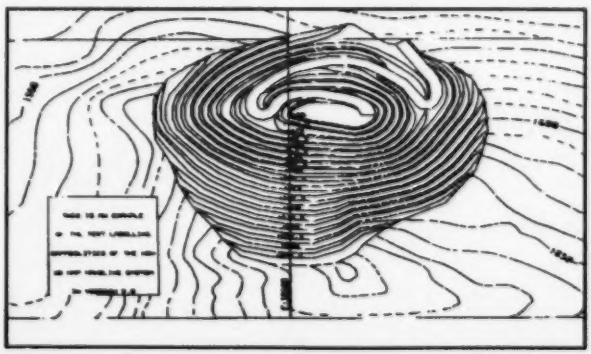


FUNCTIONAL DESCRIPTION

Project Data Management

The project data management facilities provide for user specification of all project related information including titles, units (metres or feet), dip and azimuth conventions, and data structures and formats for all project variables.

The user has full control over the specification of project variables including number (50 max), sequence, reference (descriptor or name), length, type (numeric, alpha or function) and decimals. These facilities allow the user to tailor the application of the system to suit the particular requirements of each project. The flexibility of the system is such that it can be applied to a wide range of project types, varying by mineral type, deposit type and structure, and mining method.



All system data files are project related, including basic drillhole and map data, geological and geostatistical models, mine design, planning and production models, and mine planning inventories and schedules. The file structures and directories controlling the distribution of this information are created at project specification time.

Projects may be deleted, renamed, copied (in whole or partially) or re-formatted at any stage.

Drillhole Data Management

Drillhole type data covers all information resulting from exploration drilling and includes reference, lease, collar location, category, downhole survey, and sample information. For each sample the system makes provision for specification of the full range of project variable values. Drillhole type data may also cover any data available in a similar "string" format, eg. trench, surface or face sampling results. The system provides a comprehensive range of data entry and edit facilities, including all of the standard keyboard functions, vertical and horizontal scrolling, and special functions such as data keep/recall, abort, verification and store.

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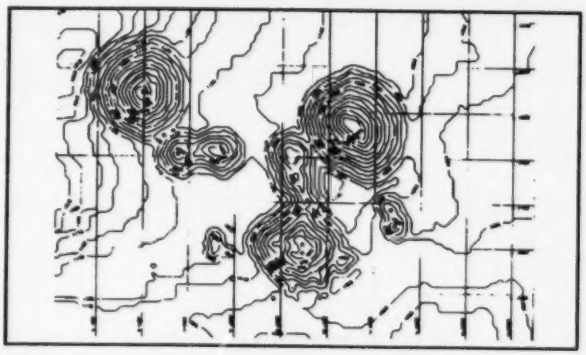
LYNX SYSTEM: DATA MANAGEMENT MODULE *(Continued)*



Drillhole information may be entered directly through the keyboard, or imported from ASCII files generated externally, or transferred directly from the microLYNX PC based system. All data editing is performed interactively through the keyboard.

Other drillhole data management facilities include drillhole selection (by reference, lease, category and/or coordinate limits), index (summary) and formatted drillhole reports, and drillhole delete and rename facilities.

Map Data Management

Map files are the data storage medium for a wide variety of data types including digitized map information (eg. roads, rivers, services, geological contacts and traces), discrete point information (eg. blasthole locations and sample values, face samples), contour information (surface offsets, isopachs, isograde), and traverse information (excavation profiles, dump profiles).

Map data files have two primary functions within the system, ie. as data sources for various technical processes, and as visual reference sources when used in a graphical overlay context. The map overlay facilities are described in more detail below. Map data files are essentially concerned with planar 2D information, however they may be extended to 2.5D by including geometric attribute values such as offset and thickness. Maps are fully 3D compatible in that,

- the 3D orientation of the map plane is stored with every map definition;
- maps may be overlayed or projected onto any viewplane orientation in 3D space.

Map data is stored in discrete point or feature format, with or without associated attribute (project variable) values. Discrete points may have a full set of project variable values associated with each point. Features are classified into lines, contours, or traverses. Other map data management facilities include merging, clipping, labelling, editing and definition of display attributes.

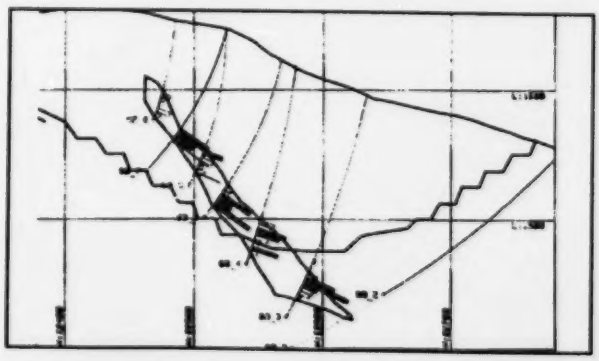
Maps may be digitized from existing documents (plans, sections, etc.), created interactively via the graphics interface, imported from externally generated ASCII format files, or (in many instances) generated by various processes within the system. Map files serve as the primary data source for all surface handling facilities provided by the system (described elsewhere).

Map Overlay Facilities

Map overlay facilities allow the use of all maps as a source of visual reference information when accessed via the interactive graphics interface. Up to fourteen maps may be overlayed and displayed simultaneously in the graphics background and used as a spatial reference or guide for various interactive processes. Overlayed maps are displayed as true 3D projections and viewplane intersections are obtained where relevant.

Production Data Management

Production data in the form of blasthole samples, face samples, excavation limits (points, profiles and surfaces) and dump limits, can all be efficiently stored, maintained and accessed in various map file formats. This information can be retrieved for use in other system processes such as excavation management and control, and determination of production quantities and grades. ■



PRODUCT INFORMATION

LYNX SYSTEM: DATA ANALYSIS MODULE *(January 1990)*

SUMMARY

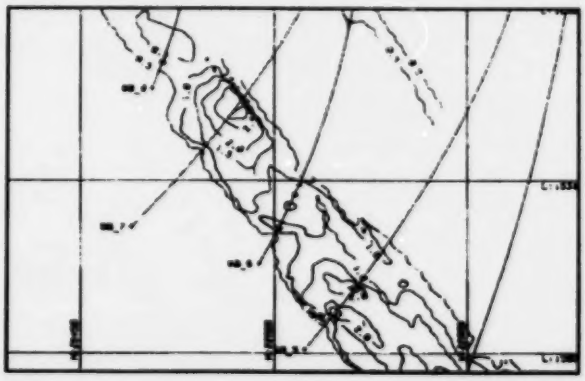
The Data Analysis (Applications) Module offers a wide range of facilities for visual, graphical, relational, statistical and stochastic analysis and interpretation of project exploration data. Drillhole plans, sections and projections in a variety of graphical formats may be displayed, with or without map overlays, at any orientation and scale in 3D space and output to a hard copy plotter. Similarly, printed reports may be obtained in a variety of tabular and graphical formats. All of the analysis functions may be applied to either original or composited drillhole sample information.

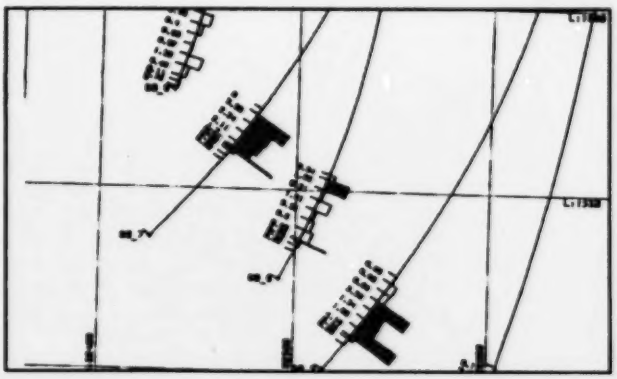
The Data Analysis Module provides the user with the necessary tools for efficient inspection, analysis and interpretation of all available data for a project prior to definition of geological and geostatistical models.

FUNCTIONAL DESCRIPTION

Drillhole Data Display

Drillhole Data Display facilities provide the user with the necessary tools for visual interpretation and analysis of drillhole type data. Information can be displayed in a variety of formats on orthogonal or rotated, inclined viewplanes. For interpretation purposes relevant map data can also be displayed in overlay mode, as described elsewhere. Drillholes may be selected prior to display by reference and category. Two primary options are available.





The Viewplane Section option displays a normal projection of drillhole traces and sample information within a specified range either side of the viewplane. Numeric sample information may be posted by value, colour grade, histogram, line contour or colour map format. Alpha information may be posted by value or colour code.

The Viewplane Projection option displays a normal projection of drillhole intersections with specified geologic (or other) units. Offsets and thicknesses of units, contacts and discontinuities are obtained by scanning all available drillhole information and displaying the results in value, line contour or colour map format. Structure contours and isopachs can be readily generated.

Data Selection

Data Selection facilities allow the user to isolate sub-populations of drillhole sample information prior to statistical or stochastic analysis. Sample information may be selected on the basis of drillhole reference and/or category, 3D coordinate limits, numeric variable limits, and alpha variable lists, in any combination. A maximum of 10000 samples at a time may be selected for further analysis.

Sub-populations of sample information may be reported in flexible, user-specified, tabular format on a printer.

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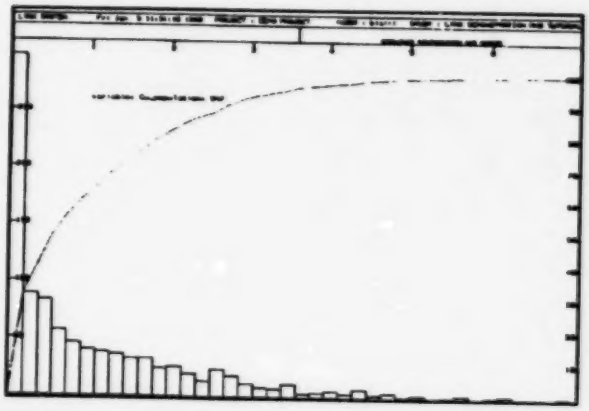
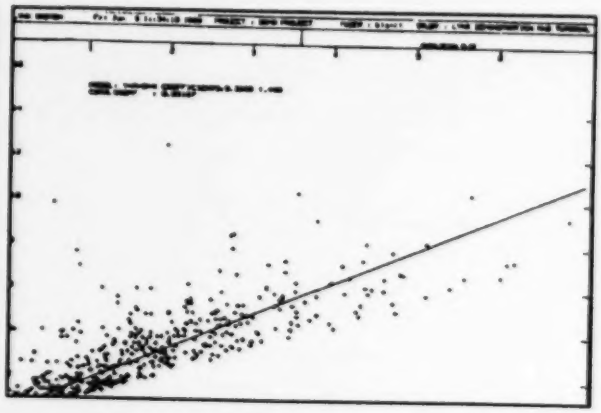
PRODUCT INFORMATION

LYNX SYSTEM: DATA ANALYSIS MODULE *(Continued)*





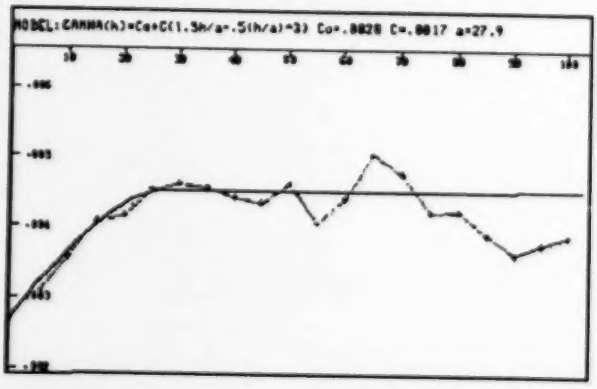
Classical Statistics

The system provides facilities for two primary forms of interactive statistical analysis, data frequency analysis and data correlation analysis. The analyses can be performed on samples from individual drillholes or on pre-selected sub-populations of sample information. A full range of facilities is provided for data weighting, range and interval specification, mathematical model fitting by regression analysis, and graphical or tabular reporting to screen or printer.

Statistical analyses may be performed on original or composited data.

Variogram Analysis

Geostatistical semi-variogram analyses may be performed on any numeric project variable, or on mathematical functions of variables. These facilities provide for analysis of the spatial variation (continuity) of sample information in three dimensions according to the theory of regionalized variables. The analyses can be performed on individual drillhole samples or on pre-selected sub-populations of sample information. A full range of facilities is provided for function definition, data normalization, specification of spacing, tolerance and increment limits, 3D directional control, and selection of semi-variogram model type. Model parameters are selected interactively and overlayed on the analysis results for visual verification. The user may choose from several semi-variogram model types. Graphical and tabular reporting to screen or printer are available. ■



PRODUCT INFORMATION

LYNX SYSTEM: GEOLOGICAL INTERPRETATION MODULE *(January 1990)*

SUMMARY

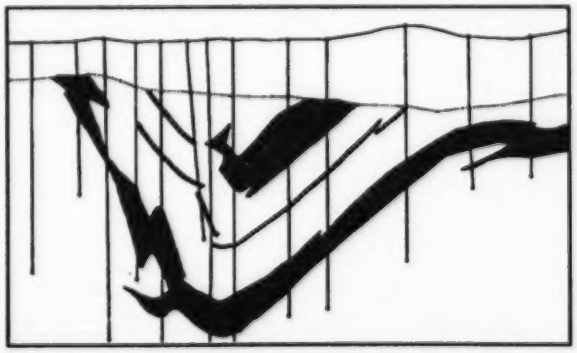
The Geological Interpretation (Applications) Module provides facilities for creating and maintaining geological and geostatistical models of a deposit. These are based on intensive application of LYNX's 3D Component Modelling technology (described elsewhere). In particular, the facilities are designed to allow the geologist to rapidly and efficiently interpret and define the structure, extent and variation of a deposit based on drillhole and map information. Any degree of structural, spatial or variational complexity, for any deposit type, can be accomodated. Facilities for data compositing and for precision reporting of geological reserves are included.

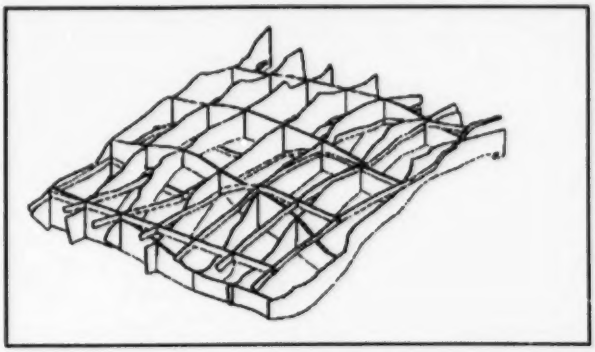
The objective of the Geological Interpretation Module is production of models which match the available geological data at all stages of mining, with sufficient detail and precision to meet the subsequent requirements of mine design, mine planning and production scheduling.

FUNCTIONAL DESCRIPTION

Geological Interpretation

In addition to its geological modelling capabilities, 3D Component Modelling offers significant advantages to the geologist involved in preliminary interpretation of deposits with structural complexity. Starting from viewplane displays of exploration data (drillhole logging and sampling, surface mapping, etc.) at any convenient orientation, the user can rapidly compile and combine sets of 2D interpretations at different orientations until a full 3D appreciation of the structure and extent of a deposit have been obtained. The full power of the interactive graphics interface is available to the user throughout the interpretive process.





Geological Modelling

The geological modelling facilities are based entirely on the application of 3D Component Modelling technology (see modelling functions) through the medium of the interactive graphics interface. The system allows the user to define the structure (eg. faults, discontinuities, marker horizons), extent (eg. geological limits, contacts, grade cutoff horizons) and variation (eg. differentiation by material type) of a deposit using 3D Component Modelling shapes to represent surfaces and enclosed volumes. Complex situations are handled interactively from whatever viewplane orientations are most convenient to the geologist and with the aid of system facilities for interpolation of surfaces between adjacent definitions. More regular situations (eg. thin-seam, tabular, multi-layered deposits) are handled by semi-automated system facilities for triangulation and translation to model components. In either case structural complexity is handled efficiently and with precision.

Other, more general, features offered by the system include the following:

- Flexible model database facilities which allow user specification of geological unit and component naming conventions and provide powerful wildcard sorting capabilities.

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LYNX SYSTEM: GEOLOGICAL INTERPRETATION MODULE *(Continued)*

- A wide range of display format, section selection, viewplane, scaling, zooming, coordinate tracking and coordinate snapping options available through the interactive graphics interface.
- 3D perspective views to assist the user in rapid visual appreciation of the spatial relationships and continuity of a deposit.
- Printer, plotter and plot file output of all screen displays, and export of plot files in industry standard format to external *CAD* systems.

Models are not limited to defining ore deposits, the facilities may equally well be applied to definition of, for example, regional geology, lithology, rock quality, seepage properties, etc. The user may create as many different geological models within a project as required, to represent different regions within a deposit, or to represent different qualities, or to reflect different levels of detail. In all cases surfaces and volumes are defined and analyzed precisely; the block, grid or wireframe approximations of traditional modelling methods are no longer a concern.

Drillhole Data Compositing

Drill logs and sample intervals can be composited to produce equivalent results at regular intervals or across recognized zones or units. Compositing can be carried out over fixed intervals with geological control. Compositing intervals may be bound by elevation limits or down-hole distances. Composited information is stored separately from original exploration information and may be accessed from other system modules as appropriate.

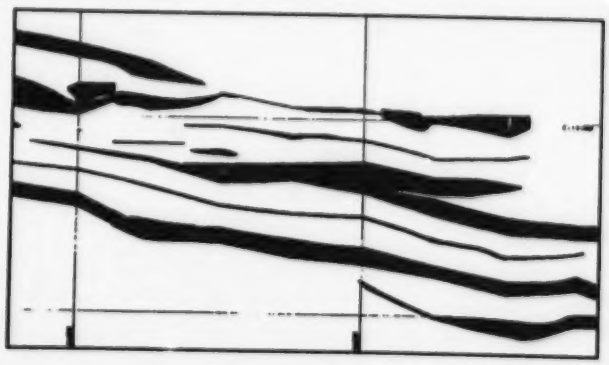
Geostatistical Modelling

Geostatistical modelling involves the representation of grade or quality distribution within the 3D shapes defining geological zones and units. Values and their variances are estimated, from drillhole or map type data, for 2D or 3D arrays of regions of influence by inverse distance, kriging or other techniques. The system provides a full range of facilities for user specification of the estimation process by variogram model, directional control, sample type, material (zone) type, and model orientation and spacing. The resulting grade or quality information may be displayed or plotted in a variety of formats on any 3D viewplane orientation. The system facilities include geostatistical array manipulation facilities which allow the generation of new variables from functions of existing modelled variables.

The orientation and spacing of geostatistical models, which control the distribution of values by region of influence, are dependent solely on geostatistical considerations such as exploration data density and quality. By application of 3D component modelling methodology, the restrictions of geological form and complexity imposed on geostatistical modelling by traditional methods are removed.

Geological Reserves

Precise geological reserves are determined by applying the volumetrics capabilities of 3D component modelling (based on 3D solids of integration) to the intersection of geological shapes with geostatistical regions of influence. Multi-variable reserve reports, based on user specified cut-off values, recovery factors and report formats, may be output directly to screen or printer; or to a standard ASCII file for subsequent import to external systems (eg. Lotus, dBASE, etc.) for report refinement and manipulation. ■



PRODUCT INFORMATION

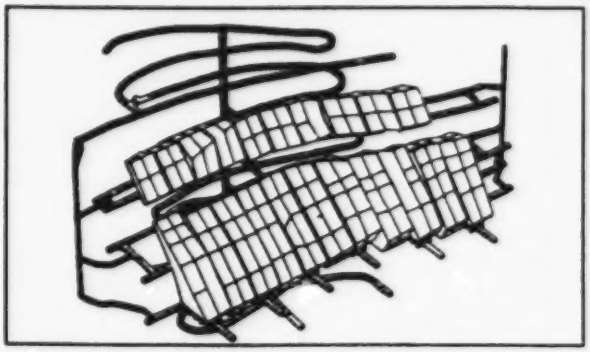
LYNX SYSTEM: UNDERGROUND MINE DESIGN MODULE *(January 1990)*

SUMMARY

The Underground Mine Design (Applications) Module provides facilities for designing mine excavation limits and mine development layouts with reference to geological and geostatistical models of a deposit; creating and maintaining models of these designs using 3D Component Modelling technology; and comparing the efficiencies of alternative mine designs. The functionality of the system allows the design engineer to define excavation limits and development layouts in the most efficient manner and orientation, whatever the deposit type or mining method. Precise reporting of mining reserves and development quantities are available at any stage. Modification and refinement of designs and models is performed via the interactive graphics interface. Thus the iterative design cycle and convergence to an optimum design solution is significantly shortened.

Mine design models utilize the same 3D component modelling technology as the associated geological and geostatistical models, however they are stored independently. The integrity of mine designs is therefore preserved at all stages. At the same time, the common modelling methodology allows models to be overlayed and intersected, thus providing an integrated solution to all phases of mining operations.

The objectives of the Mine Design Module are twofold, firstly to provide an efficient platform for underground mine design and optimization, and secondly to produce design models which will form the basis of subsequent mine planning and production scheduling operations.



FUNCTIONAL DESCRIPTION

General Design Features

General design features provided by the system include the following.

- Background (reference) displays of geological and/or geostatistical models, existing mine excavation and development models, and drillhole or map data overlays.
- Selection of design viewplane orientations which are completely independent of deposit model orientations and chosen to suit the mining method.
- Flexible model database facilities which allow user specification of design unit and component naming conventions and provide powerful wildcard sorting capabilities.
- A wide range of display format, section selection, viewplane, scaling, zooming, coordinate tracking and coordinate snapping options available through the interactive graphics interface.
- 3D perspective views to assist the user in rapid visual appreciation of the spatial relationships of mine geometry.

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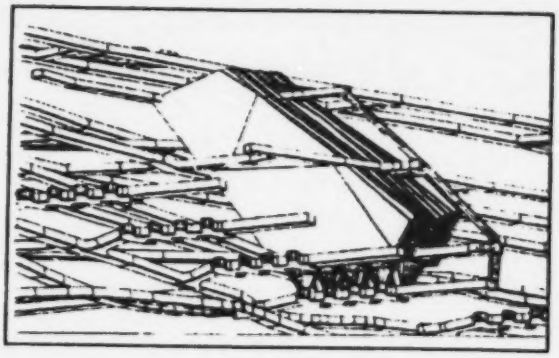
LYNX SYSTEM: UNDERGROUND MINE DESIGN MODULE *(Continued)*



- Printer, plotter and plot file output of all screen displays, and export of plot files in industry standard format to external *CAD* systems.

Excavation Design

Excavation limits are designed interactively with reference to a background display of whatever information is relevant to the design process (eg. structure, grade, rock quality, existing limits, etc.). The orientation of the design viewplane may be selected to suit the mining method, eg. cut and fill design in plan, open stoping design on section normal to deposit strike, panel stoping design in the plane of the seam or vein deposit. Excavation limits are translated into 3D component modelling shapes which define excavation surfaces and enclosed volumes; the continuity of excavation limits in the third dimension is ensured by the boundary interpolation features of the modelling functions. The design of panel stopes for thin seam type deposits may optionally be handled by the powerful surface handling facilities (triangulation, clipping, surface manipulation, etc.) offered by 3D component modelling. Immediate on screen analysis of excavation volumes and grades is a powerful design option.

Excavation limits may be readily adjusted at any stage to suit design refinements and/or the availability of new exploration information. The level of detail incorporated in a mine design model is entirely at the user's discretion and the user may maintain as many design models as necessary for a particular project. Different models may represent different mining regions, varying levels of detail, or alternative mining solutions.

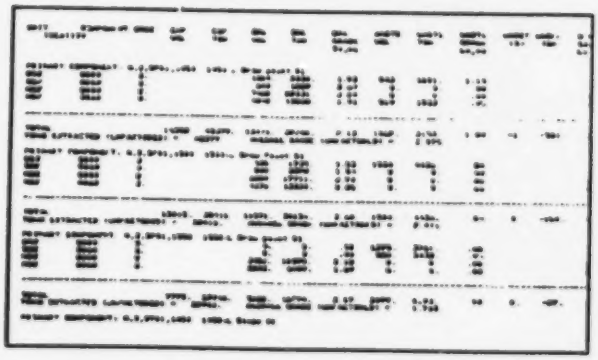
Mine Development Design

In addition to the facilities described above the following specialized facilities are provided for mine development design and modelling.

- Automatic generation of straight, curved and graded units of constant cross-section.
- Interactive definition of ramps of constant cross-section and varying geometry (curvature and grade).
- Definition of standard development components and multiple re-assignments at different locations.
- The use of CAD tools which allow the design engineer to honour grade and curvature constraints while maintaining necessary clearances.
- Efficient definition of large volumes of existing mine geometry information from plans and sections via the digitizing table.
- The use of 3D map and multiple overlay facilities for definition of a variety of mine service layouts and other development information.
- The use of 3D map facilities for definition and design of drillhole and blast patterns and layouts.
- Precise reporting of mine development quantities for estimation purposes.

Mining Reserves

Precise mining reserves are determined by applying the volumetrics capabilities of 3D component modelling (based on solids of integration) to the intersection of mining shapes with associated geological shapes and geostatistical regions of influence. Multi-variable reserve reports, based on user-specified cut-off values, recovery factors and report formats, may be output directly to the screen or printer; or to a standard ASCII file for subsequent import to external systems (eg. Lotus, dBASE, etc.) for report refinement and manipulation. The mining reserves capabilities are equally applicable to mine excavation and mine development models. ■



PRODUCT INFORMATION

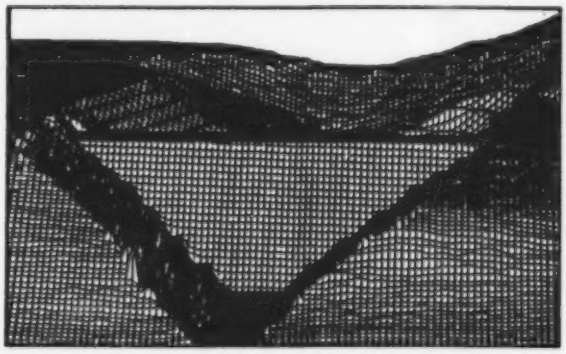
LYNX SYSTEM: OPEN PIT MINE DESIGN MODULE *(January 1990)*

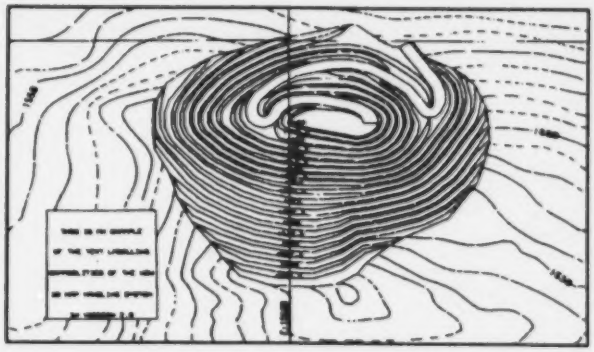
SUMMARY

The Open Pit Mine Design (Applications) Module provides facilities for designing surface mining excavation limits with reference to geological and geostatistical models of a deposit; creating and maintaining models of these designs using 3D Component Modelling technology; and comparing the efficiencies of alternative mine designs. The functionality of the system allows the design engineer to define excavation limits in the most efficient manner and orientation, whatever the deposit type or mining method. Design features offered by the system include 3D Pit Optimization and Conical Pit Expansion techniques. Precise reporting of mining reserves is available at any stage. Modification and refinement of designs and models is performed via the interactive graphics interface. Thus the iterative design cycle and convergence to an optimum design solution is significantly shortened.

Mine design models utilize the same 3D component modelling technology as the associated geological and geostatistical models, however they are stored independently. The integrity of mine designs is therefore preserved at all stages. At the same time, the common modelling methodology allows models to be overlayed and intersected, thus providing an integrated solution to all phases of mining operations.

The objectives of the Mine Design Module are twofold, firstly to provide an efficient platform for surface mining design and optimization, and secondly to produce design models which will form the basis of subsequent mine planning and production scheduling operations.





FUNCTIONAL DESCRIPTION

General Design Features

General design features provided by the system include the following.

- Background (reference) displays of geological and/or geostatistical models, existing mine excavation, and drillhole or map data overlays.
- Selection of design viewplane orientations which are completely independent of deposit model orientations and chosen to suit the mining method.
- Flexible model database facilities which allow user specification of design unit and component naming conventions and provide powerful wildcard sorting capabilities.
- A wide range of display format, section selection, viewplane, scaling, zooming, coordinate tracking and coordinate snapping options available through the interactive graphics interface.
- 3D perspective views to assist the user in rapid visual appreciation of the spatial relationships of mine geometry.
- Printer, plotter and plot file output of all screen displays, and export of plot files in industry standard format to external *CAD* systems.

3D Pit Optimization

The 3D pit optimization facility, which uses the well known Lerchs-Grossman algorithm, provides an automated method for generating preliminary open pit designs based

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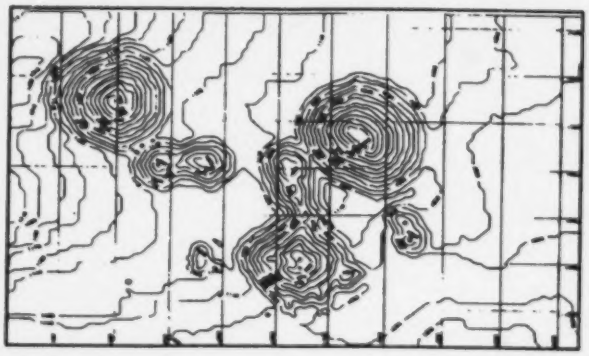
LYNX SYSTEM: OPEN PIT MINE DESIGN MODULE *(Continued)*



on economic criteria. The method is based on a 3D model of net $ values, generated from geostatistical models of relevant grades, and taking into account recoverable commodity values, mining and processing costs, haulage costs, etc. Haulage costs which increase with pit depth may be incorporated into the model. The method optimizes the total net profit from the mining operation, considering the maximum allowable wall slopes in different directions to obtain the excavation design limits. The LYNX implementation of the Lerchs-Grossmann algorithm is a stable, efficient product, renowned for its processing speed. The optimized designs may be used as the basis for detailed pit designs in the design facilities described below.

Excavation Design

Excavation limits are designed interactively with reference to a background display of whatever information is relevant to the design process (eg. structure, grade, rock quality, existing limits, etc.). In addition to 3D pit optimization, several other design options are available.

- The interactive conical pit expansion design technique may be applied in top-down or bottom-up model as required, to either open pit or dump design. Wall slope and bench width criteria may be varied vertically and horizontally throughout the plan area of the design to suit geological, geotechnical and mining constraints.
- Final, detailed pit designs in plan, with all the necessary detail of haul roads, push-backs, drainage, etc., may be defined and entered into the system via the digitizer and the comprehensive 3D map handling facilities described elsewhere.

In all cases the resulting excavation design may be translated into 3D component models for further refinement and/or mining reserves analysis. Alternatively, the user may apply the design capabilities of 3D component modelling directly. The orientation of the design viewplane may be selected to suit the mining method and excavation geometry, eg. bench plans or sections normal to deposit strike. The continuity of excavation limits in the third dimension is ensured by the boundary interpolation features of the modelling functions. Immediate on-screen analysis of excavation volumes and grades is a powerful design option.

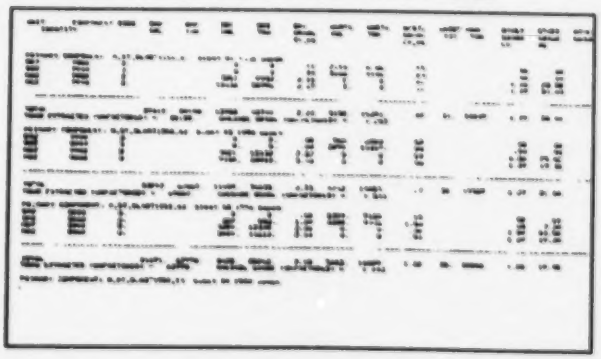
Mine Modelling

Excavation limits are translated into 3D component modelling shapes which define topographical and/or excavation surfaces and enclosed volumes. The automatic generation of mine models is handled by the powerful surface handling facilities (triangulation, clipping, surface manipulation, etc.) offered by 3D component modelling.

Excavation limits may be readily adjusted at any stage to suit design refinements and/or the availability of new exploration information. The level of detail incorporated in a mine design model is entirely at the user's discretion and the user may maintain as many design models as necessary for a particular project. Different models may represent different mining regions, varying levels of detail, or alternative mining solutions.

Mining Reserves

Precise mining reserves are determined by applying the volumetrics capabilities of 3D component modelling (based on solids of integration) to the intersection of mining shapes with associated geological shapes and geostatistical regions of influence. Multi-variable reserve reports, based on user-specified cut-off values, recovery factors and report formats, may be output directly to the screen or printer; or to a standard ASCII file for subsequent import to external systems (eg. Lotus, dBASE, etc.). ■



PRODUCT INFORMATION

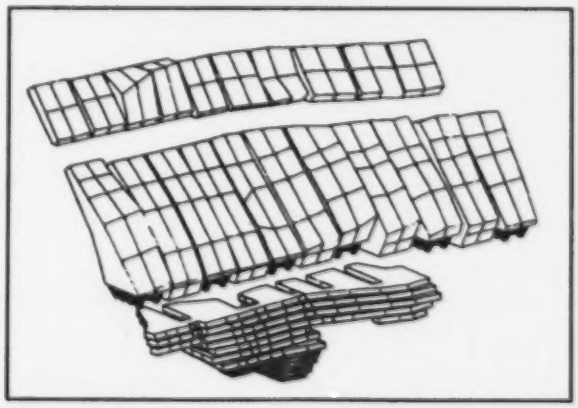
LYNX SYSTEM: PLANNING AND SCHEDULING MODULE *(January 1990)*

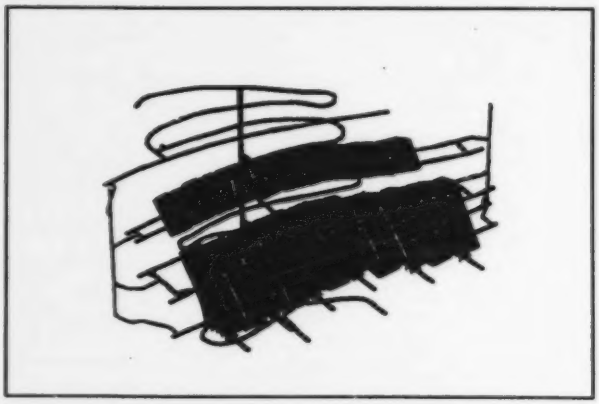
SUMMARY

The Planning and Scheduling (Applications) Module provides facilities for re-organizing of 3D component models representing mine designs to suit planning requirements and constraints; for determination of an inventory of mine planning units; for scheduling of mine activities and resources concerned with excavation; and for forcasting of mine production. The system provides several options for interactive scheduling of mining activities, and ready access to existing schedules for refinement and redefinition. Production forcasting is based on CPM network analysis and final results are available in the form of activity, grade and tonnage reports in graphical or tabular format. The module is designed to be applied in a mode of iterative refinement of mine plans and schedules, converging to an optimum mining sequence, and requires intensive interaction with the mine planning engineer.

The module is fully integrated with LYNX's 3D component modelling technology, thus ensuring a smooth flow of information from geological interpretation, through mine design, to the mine planning phase. The module is equally applicable to both surface and underground mining operations, and to short, medium or long-term planning and scheduling operations.

The prime objectives of the Planning and Scheduling Module are to dramatically shorten the planning and scheduling cycle, and to allow the planning engineer to concentrate on obtaining an optimum mining sequence which satisfies mine production requirements.





FUNCTIONAL DESCRIPTION

Mine Planning Model

Mine planning models are derivatives of the 3D component model representations of mine designs, based on the concept of mine planning units which are representative of the mining method, the planning mode (short, medium or long-term), and the scale of the project. The size and the complexity (level of detail) of planning units are also dependent on the planning and scheduling mode. Typically, for long-term planning, the smallest planning unit would correspond to an underground stope, or to a mining bench or phase. For short-term planning, or production scheduling, the planning unit size would be reduced to (for example) a blast ring, or a ramp development unit, or a bench production unit, and the level of detail would be increased accordingly.

The planning facilities provide the user with the ability to selectively combine and redefine one or more mine design models into a mine planning model, by combining and re-naming sets of mine design components into logical mine planning units. The resulting mine planning model is fully compatible with the system modelling functions and all of the mine design applications facilities described elsewhere.

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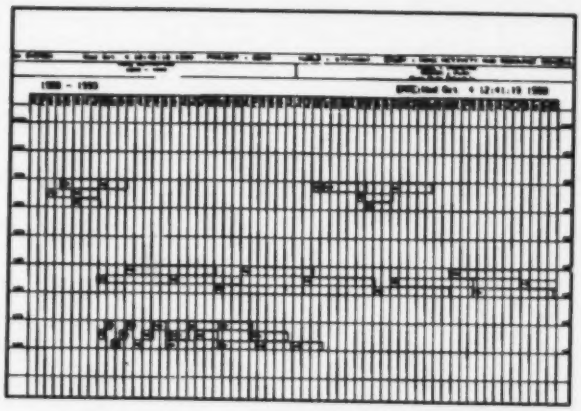
PRODUCT INFORMATION

LYNX SYSTEM: PLANNING AND SCHEDULING MODULE *(Continued)*



Mine Planning Inventory

The determination of an inventory of mine planning units is based on the application of the 3D volumetric analysis capabilities of 3D component modelling to the mine planning model, and the resulting ability to determine precise grade and tonnage reserves for units of any size or complexity. The inventory of mine planning units contains the following information for each unit.

- 3D geometry and spatial location.
- Material types (geological codes) intersected by the unit.
- Volumes, densities and tonnages for each grade variable by material type.
- Grade values for each material type for a range of cut-off values.

The resulting inventory is reported and stored in file form for subsequent access by the mine activity and resource scheduling facilities described below. If desired, the inventory file may be accessed from other sources for processing externally to the system.

Mine Activity and Resource Scheduling

The mine activity and resource scheduling facilities may be applied to the simulation of mining production over all, or a portion, of the life of a mining project. The primary objective of the scheduling process is to optimize the sequence of mining activities, based on the inventory of mine planning units, to satisfy key production requirements, typically grade and tonnage output. This is generally an iterative process and is achieved by cycling through the scheduling and reporting processes, and possibly the mine planning and inventory processes described above, until the optimum schedule is obtained. Several interactive options for activity sequencing are provided including equipment sequencing, direct activity sequencing, and the specification of sequence constraints. By application of these facilities in various combinations the user may generate complex networks of activities, including parallel, series, forward branching and backward branching network configurations. Other interactive scheduling features offered by the system include the following.

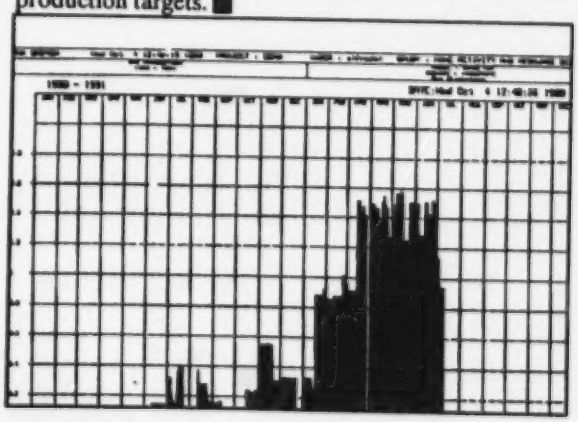
- Automatic generation of mining activities from the planning unit inventory.
- Specification of a calendar of available work days, incorporating holidays and shut-downs.
- Pegging of activity start dates.
- Automatic checking of the sequence, using CPM network techniques, against the user specified constraints (eg. geometric constraints, fixed start dates, activity precedences) each time a new entry is made.
- Reporting of scheduling conflicts for corrective action by the user.
- A range of detailed scheduling reports designed to assist the user with sequence analysis and refinement.

Mine Production Forcasting

The final step in the planning and scheduling process is production forcasting, based on the application of CPM network analysis techniques. A range of reporting options is provided, in graphical or tabular format, including the following.

- Activity Gantt charts (bar charts).
- Production grades vs. time for each grade variable.
- Production tonnages vs. time for ore and waste materials.

A useful scheduling feature, available in graphics mode, is the automatic modification of activity production rates within a specified time period in order to meet specified production targets. ■



PRODUCT INFORMATION

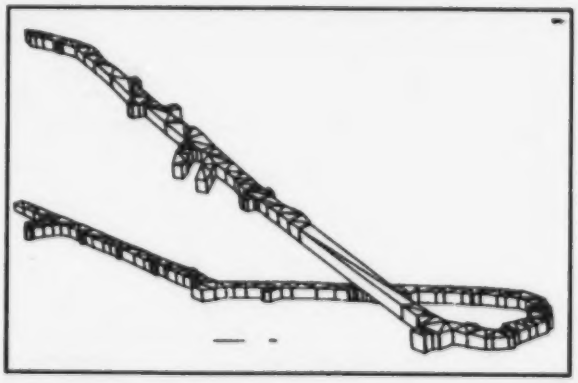
LYNX SYSTEM: UNDERGROUND PRODUCTION CONTROL MODULE

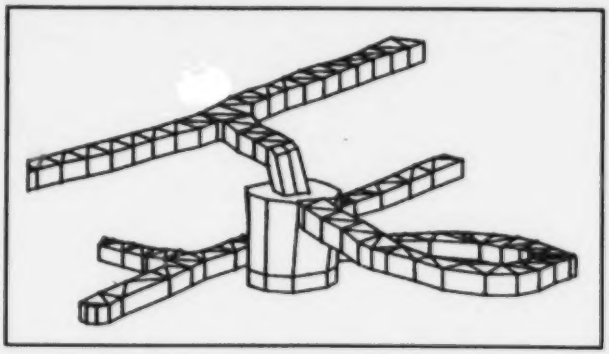
(January 1990)

SUMMARY

The Underground Production Control (Applications) Module provides facilities for excavation and grade control, and facilitates reconciliation of production results with predicted (planned and scheduled) quantities. The excavation and grade control facilities utilize 3D component modelling technology to generate mine production models, which represent the "as mined" conditions, based on surveyed excavation limits and in-situ sample grade values respectively. In this way complete and precise production models of mine excavation, development and grade distribution can be created and maintained, keeping pace with the overall progress of a mining project. Application of the 3D volumetric analysis capabilities of the modelling functions provides the means for determining precise production quantities and grades. These in turn provide the basis for mine production control and reconciliation.

The production models are compatible with the full range of modelling functions provided by the system for geological, geostatistical, design and planning models, thus ensuring an integrated solution to all phases of mining operations. The production models can also be used as background reference displays for the design and planning of mine extensions, and for the planning of exploration drilling operations.





FUNCTIONAL DESCRIPTION

Excavation Control

The excavation control facilities allow the user to construct 3D component modelling shapes representing excavated stopes, mine development, etc. from underground survey information. The methodology is based on reduced survey results in the form of XYZ coordinates from hanging-wall, foot-wall and side-wall observations of the excavation limits. Interactive facilities allow the user to define the extent of the excavation limits, to tie back the limits to existing excavation shapes (ensuring continuity of surfaces), and to define the topology of connecting surfaces by triangulation. The system generates triangulated modelling components which fill the excavation void, completely defining the surface limits and enclosed volume of the excavation.

The survey information required by the system may originate from one or more of the following sources.

- Keyboard entry of reduced survey field notes.
- Transfer of XYZ information in standard ASCII file format from an external survey reduction facility.
- Import of ASCII files from a total station survey instrument.

The resulting mine production excavation model is fully compatible with all of the modelling functions provided by the system and described elswhere, including 3D volumetrics analysis, section, plan and perspective displays and plots, and background display capabilities.

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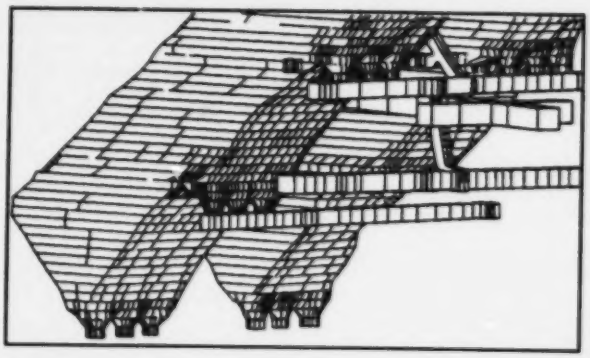
PRODUCT INFORMATION

LYNX SYSTEM: UNDERGROUND PRODUCTION CONTROL MODULE
(Continued)



Existing Excavations

In the case of an operating mine with existing excavation information already defined on plan and section documents, this information may be entered via the digitizer and converted into 3D component modelling shapes using the applications facilities described under Underground Mine Design. Several options exist depending on the type and configuration of mining excavation.

- In the case of typical, irregular stoping excavations, a series of boundaries on parallel sections (ie. excavation contours) may be digitized and subsequently linked to form a set of 3D modelling shapes.
- Alternatively, in the case of panel type excavations, the powerful surface handling facilities may be used to generate triangulated component shapes connecting digitized control points.

The resulting excavation model may then be merged and extended with modelling shapes generated under the excavation control facilities described above.

Grade Control

By applying the grade modelling facilities provided by 3D component modelling to sample grade values obtained from in-situ sampling techniques within the excavations, the user may generate grade models which are associated directly with the previously excavated material, and with the adjacent material remaining in the planned excavation. The grade values and their associated 3D coordinates may be entered either via the keyboard or via the digitizer and stored in map data files, from where they can be accessed directly by the modelling functions. The in-situ grade values may optionally be combined with original exploration values, depending on the desired result. The resulting production grade model is fully compatible with all of the modelling functions provided by the system, and may be utilized as the basis for improved short-term production grade control and scheduling. It may also be used for reconciliation with predicted grade distributions.

The production grade model may be compared directly with predicted grades by applying the 3D array manipulation facilities described elsewhere. An analysis of the resulting differences in value, variance and distribution provides a measure of the validity and/or efficiency of the original, predictive modelling parameters and algorithms, and the exploration techniques. These can subsequently be modified and/or refined and applied more precisely to unmined regions of the mine.

Production Control and Reconciliation

The 3D volumetrics facilities provided by the modelling functions and applied to the mine planning excavation model in conjunction with the production grade model provide the basis for more accurate production control and short-term scheduling. In this application, 3D mining shapes from the planning excavation model are intersected with geological shapes and regions of influence from the production grade model to obtain improved short-term production quantities and grades.

Similarly, if the 3D volumetrics facilities are applied instead to the production excavation model and the production grade model then precise "as mined" production quantities and grades are obtained. The results can be exported in ASCII file format to an external facility (eg. Lotus, dBASE) where they can be compared directly with equivalent predicted mining reserve results from the mine design and planning models, and with mill head results. ■